



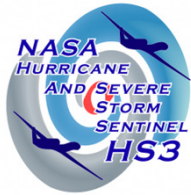
# Impact of Assimilation of HS3 Global Hawk Dropsonde Observations on Hurricane Track and Intensity Forecasts from NCEP Operational HWRF Model

**Vijay Tallapragada, Emily Liu, Weiguo Wang and Chanh Kieu**

**Environmental Modeling Center,  
NCEP/NOAA/NWS, NCWCP, College Park, MD 20740.**

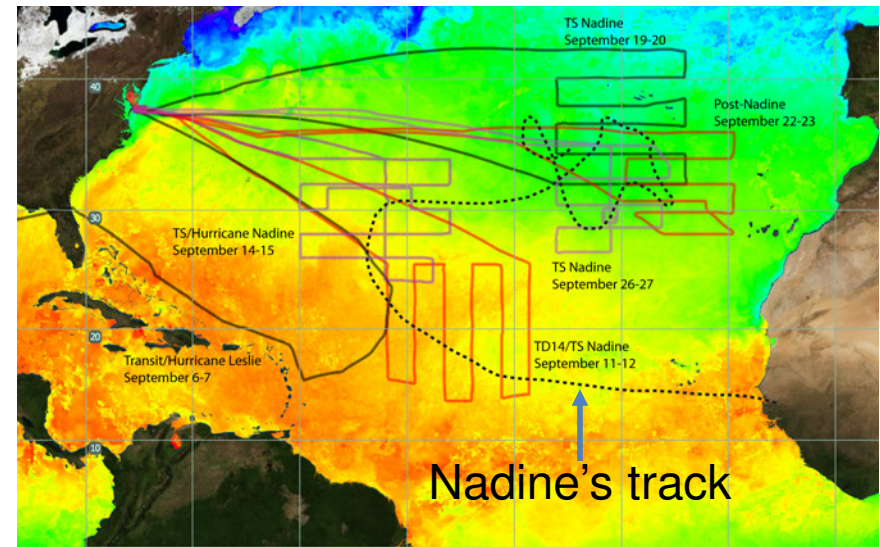
***HS3 Science Meeting, NASA Ames, Mountain View, CA; April 29 – May 1, 2014***





# Hurricane and Severe Storm Sentinel

- Multi-year mission targeted to investigate the processes that underlie hurricane formation and intensity change in the Atlantic-Caribbean-Gulf region in the years 2012, 2013, and 2014.
- Two Global Hawks unmanned aircraft system (UAS)
  - High-altitude, long endurance aircraft
  - One equipped for the **storm environment** (FL#872), one for **over-storm** flight (FL#871)
  - 4-5 week Deployments of GHs in 2012-2014 from Wallops Flight Facility in VA



HS3 research flights for hurricane Nadine (Credit: NASA)

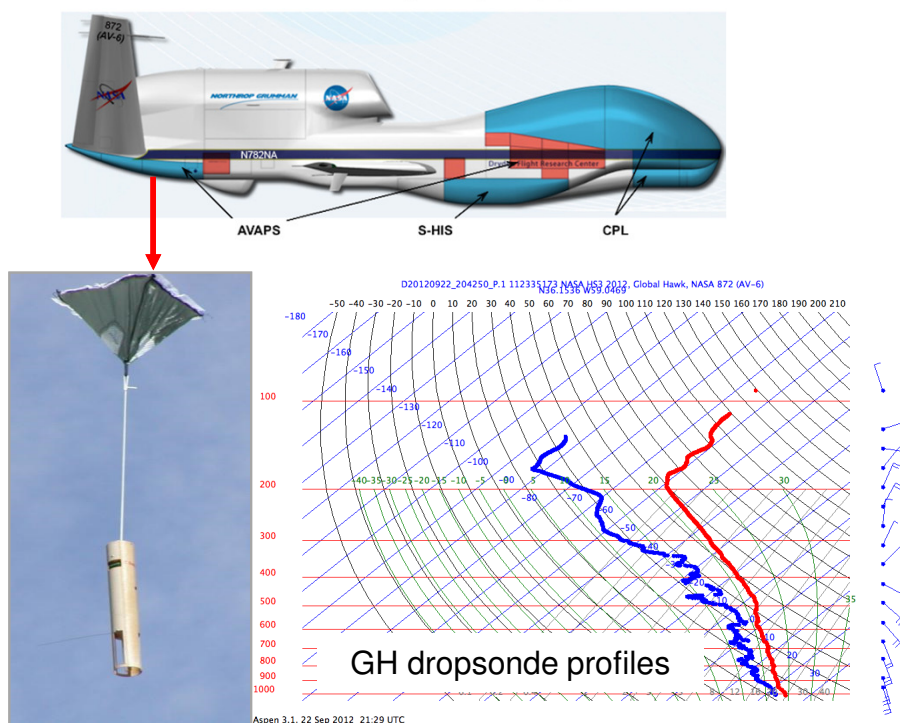
Year	Period	Storm
2012	Sept 07 – Sept 26	Nadine
2013	Aug 20 – Sept 23	Gabrielle Humberto

Tropical Storms with GH dropsondes

# Global Hawk Dropsondes

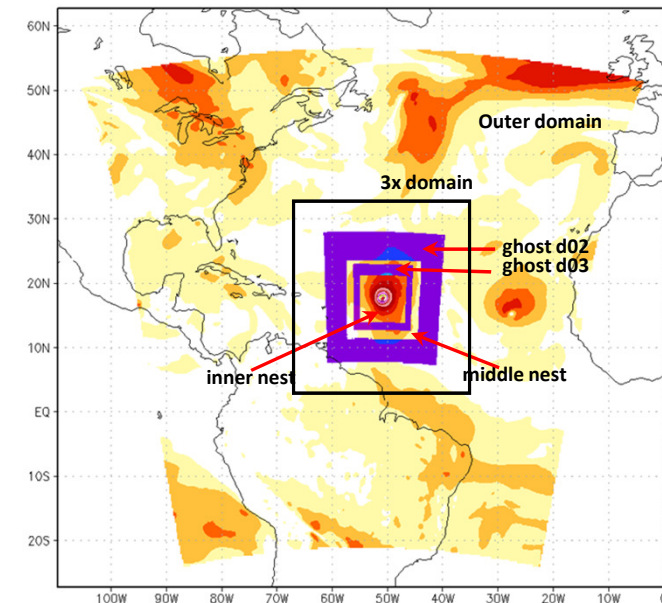
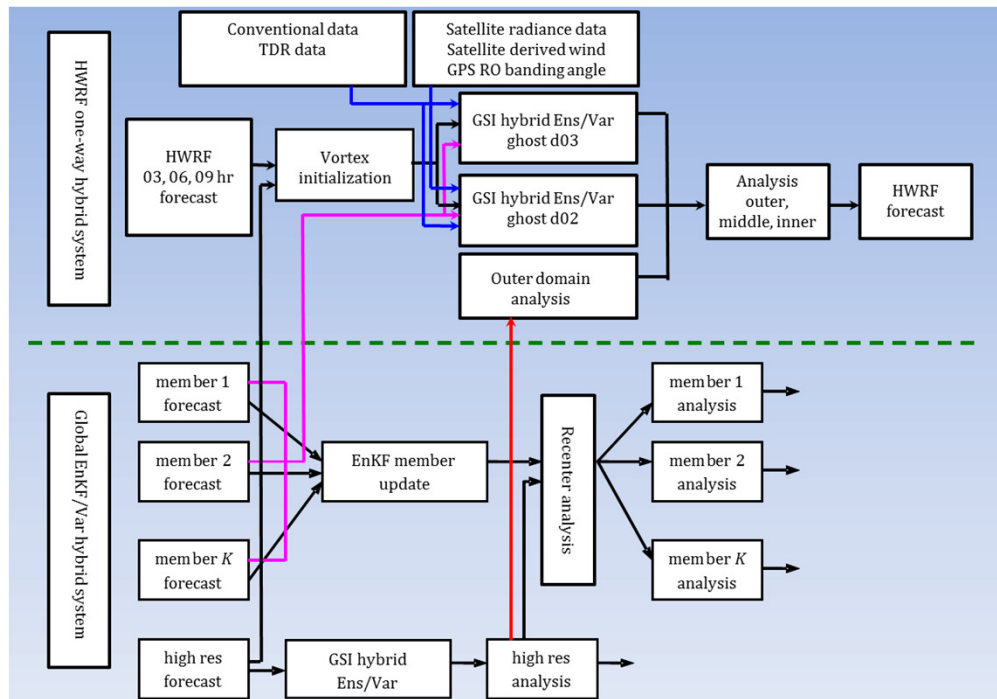
- Airborne Vertical Atmospheric Profiling System (AVAPS)
  - System has 88-sonde and 8-channel capacity so it can track 8 sondes simultaneously
- Dropsonde characteristics:
  - Sensors based on Vaisala RS-92 radiosonde sensor module
  - Winds based on OEM GPS receiver and position

HS3 Environmental Payload (AV-6) @ WFF '13



Observation	Conversion for DA
UTC Time	
Latitude/Longitude	
Pressure	
Dry-bulb temperature	Virtual Temperature
Relative humidity	Specific Humidity
Wind Speed	U- & V-component
Wind Direction	Winds

# HWRF Data Assimilation System Upgrades for 2014 Implementation



- Data assimilation performed on ghost d02 (20°x20°, 9km) and ghost d03 (10°x10°, 3km) after vortex initialization. GFS analysis is used in outer domain. No DA for outer domain.
- GSI hybrid analysis using global EnKF 80 ensemble member.
- First guess:
  - TC environment cold start from GDAS forecast
  - TC vortex cycled from HWRF forecast
  - First Guess at Appropriate Time (FGAT)
- Observational data:
  - ghost d02: conventional data (including dropsonde data), TDR data and Satellite Data
  - ghost d03: conventional data (including dropsonde data) and TDR data (no satellite data for 3km analysis)

Satellite radiance assimilation for 9km (ghost\_d02) domain:

- use GFS-HWRF blended vertical coordinate (75 levels)
- use bias correction estimations from global analysis
- use GFS ozone profiles

Satellite Data:

Radiances from IR instruments (HIRS,AIRS, IASI, GOES Sounders), Radiances from MW instruments (AMSU-A, MHS, ATMS), Satellite derived wind, GPS RO bending angle

## Data assimilation upgrades for operational HWRF for 2014 hurricane season

1. Apply regional hybrid GSI analysis for both D2 (9km) and ghost (3km) domains
2. Assimilate the conventional data and TDR, GSPRO, satellite derived wind, brightness temperature from IR instruments (HIRS, AIRS, IASI, GOES Sounder) and MW instruments (AMSU-A, MHS, ATMS)
3. Set satellite thinning box to 90 KM for IR instruments, and 45 KM for MW instruments
4. Change 3-hourly FGAT to hourly FGAT – provide more accurate first guess fields, especially for fast moving and developing storms
5. Further refinements in TDR data assimilation including advanced thinning strategies and removal of surface pressure flag (include it in assimilation); add dropsonde data in the inner core when available (especially temperature and moisture data; *winds within 3\*RMW excluded*).

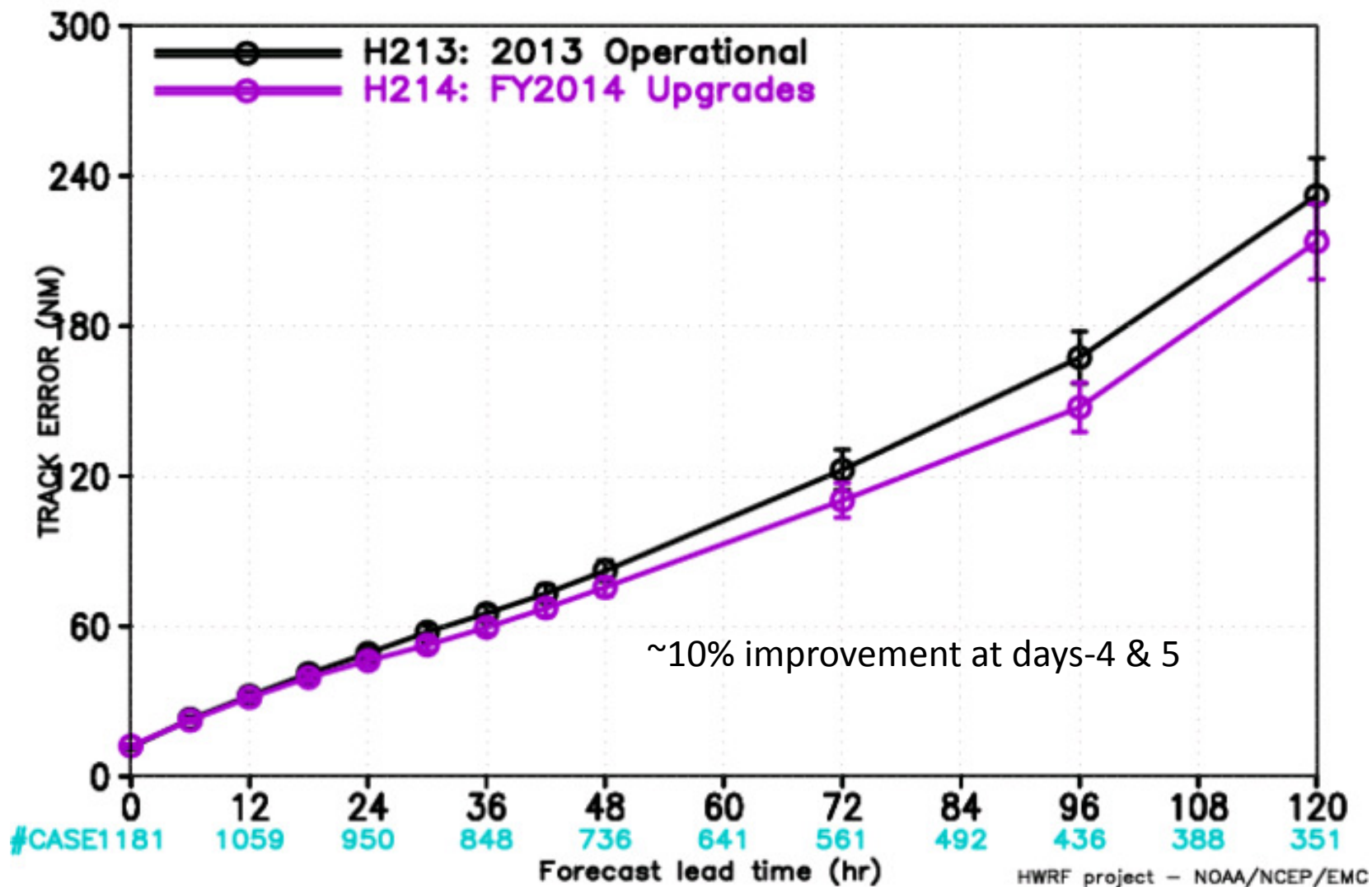
Expt	D01 (27km)	ghost_d02 (9km)	ghost_d03 (3km)
T14C	Using GFS analysis	20°x20°	10°x10°
		Conventional, satellite radiance, satellite wind, GPS RO, TDR and dropsondes (excluding inner-core winds)	Conventional, TDR and dropsonde (excluding inner core winds)



# 2014 HWRF Final Results: Atlantic Track Errors 2008-2013

## Late Model Verification

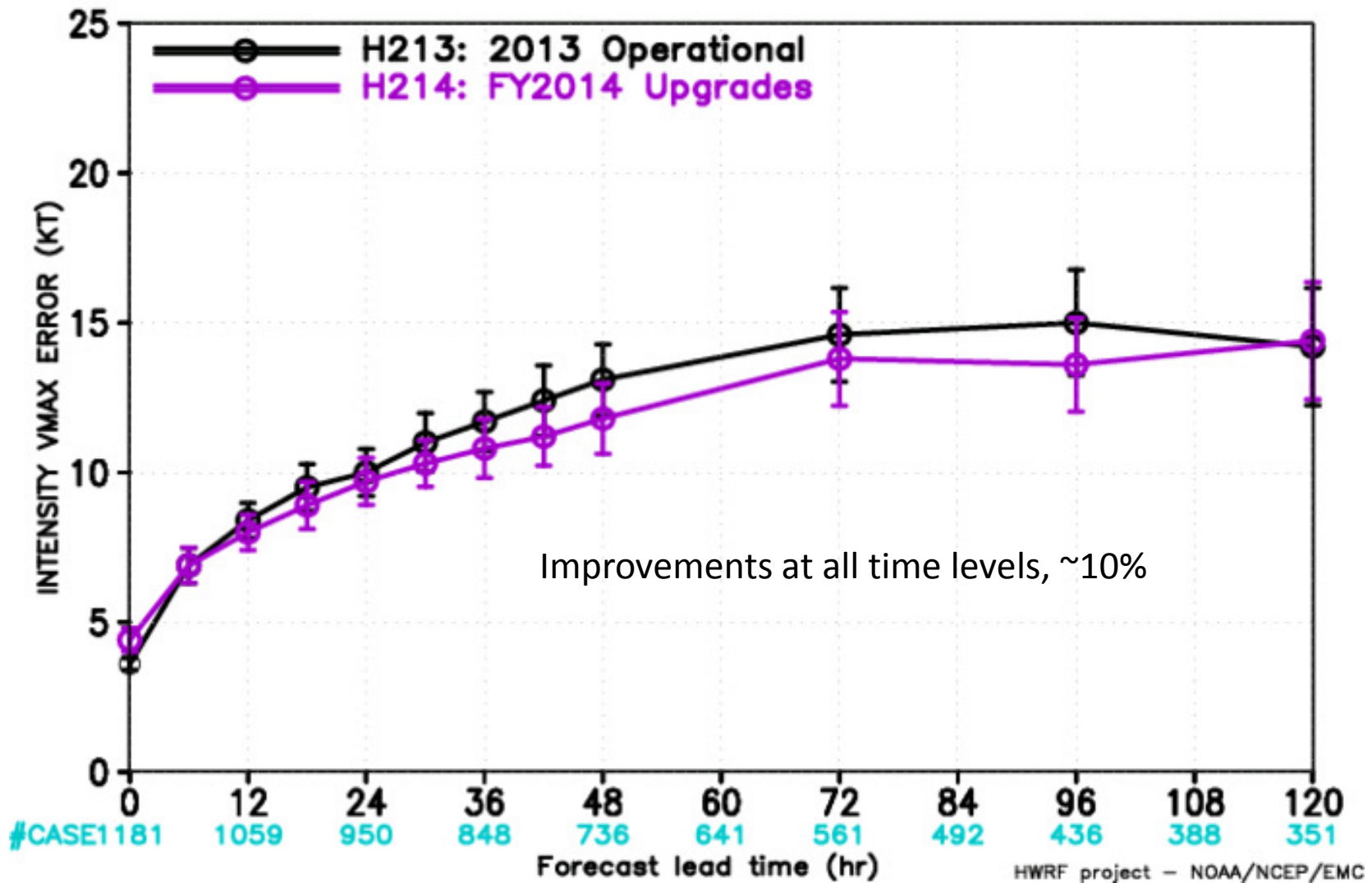
HWRF FORECAST – TRACK ERROR (NM) STATISTICS  
VERIFICATION H213 & H214 ATL 2008–2013

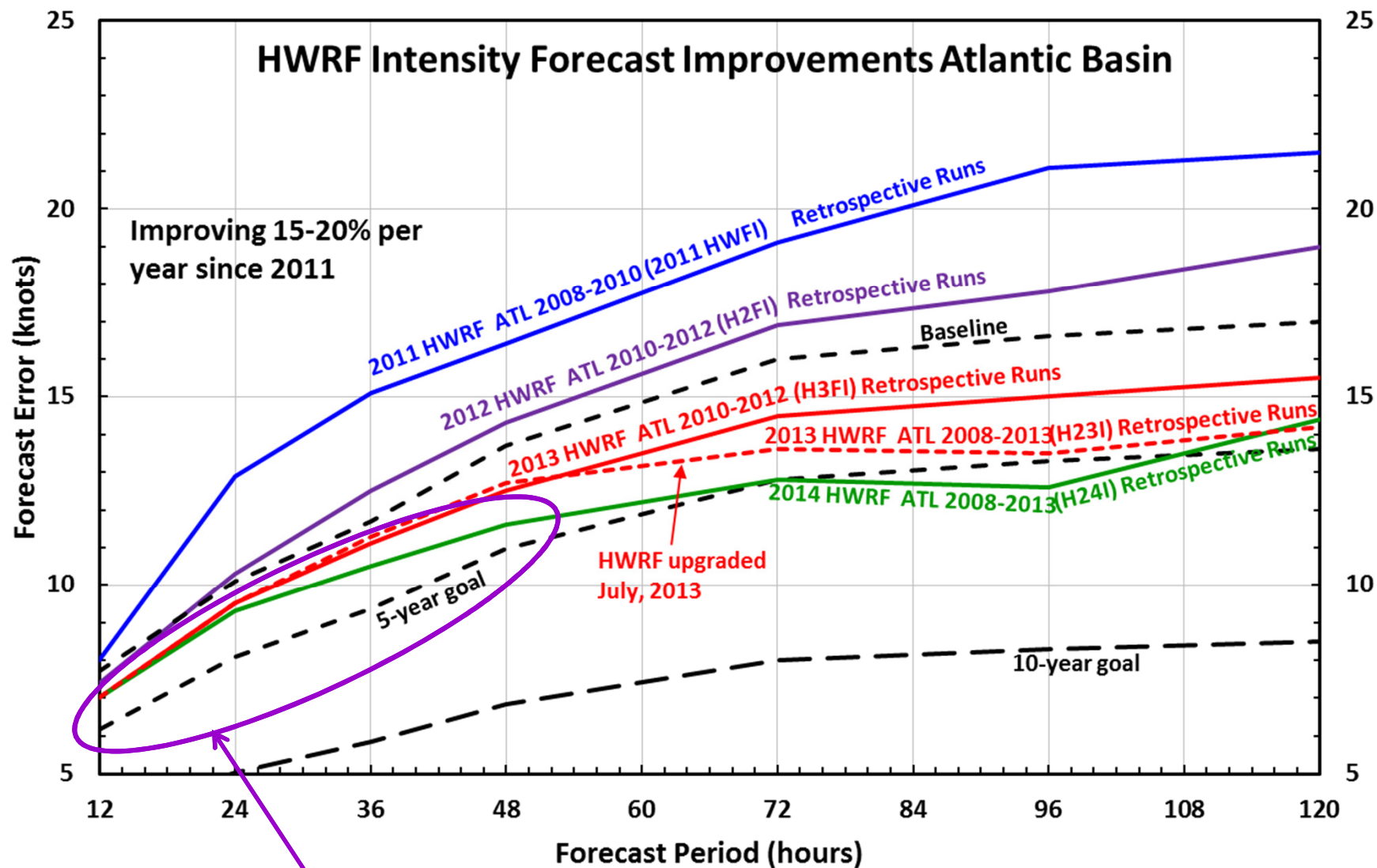


# 2014 HWRF Final Results: Atlantic Intensity Errors 2008-2013

## Late Model Verification

HWRF FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS  
VERIFICATION H213 & H214 ATL 2008–2013



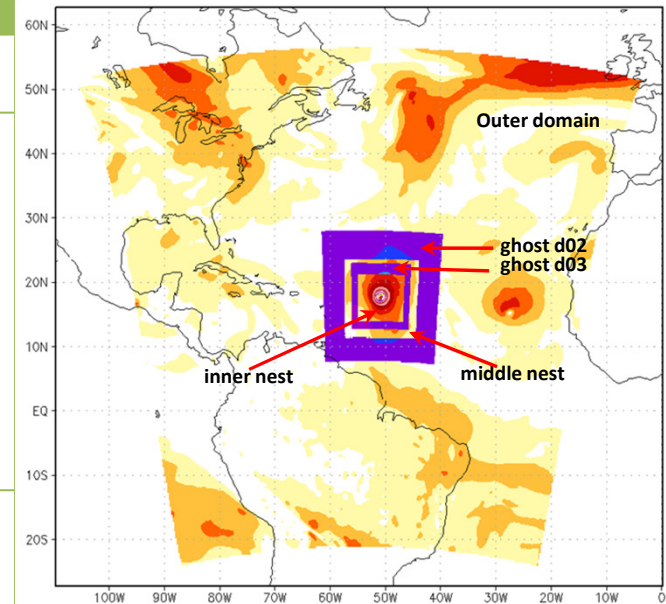


Focus area for improvements: Much to do with getting more accurate initial vortex structure and environment (where observations and DA are critical)



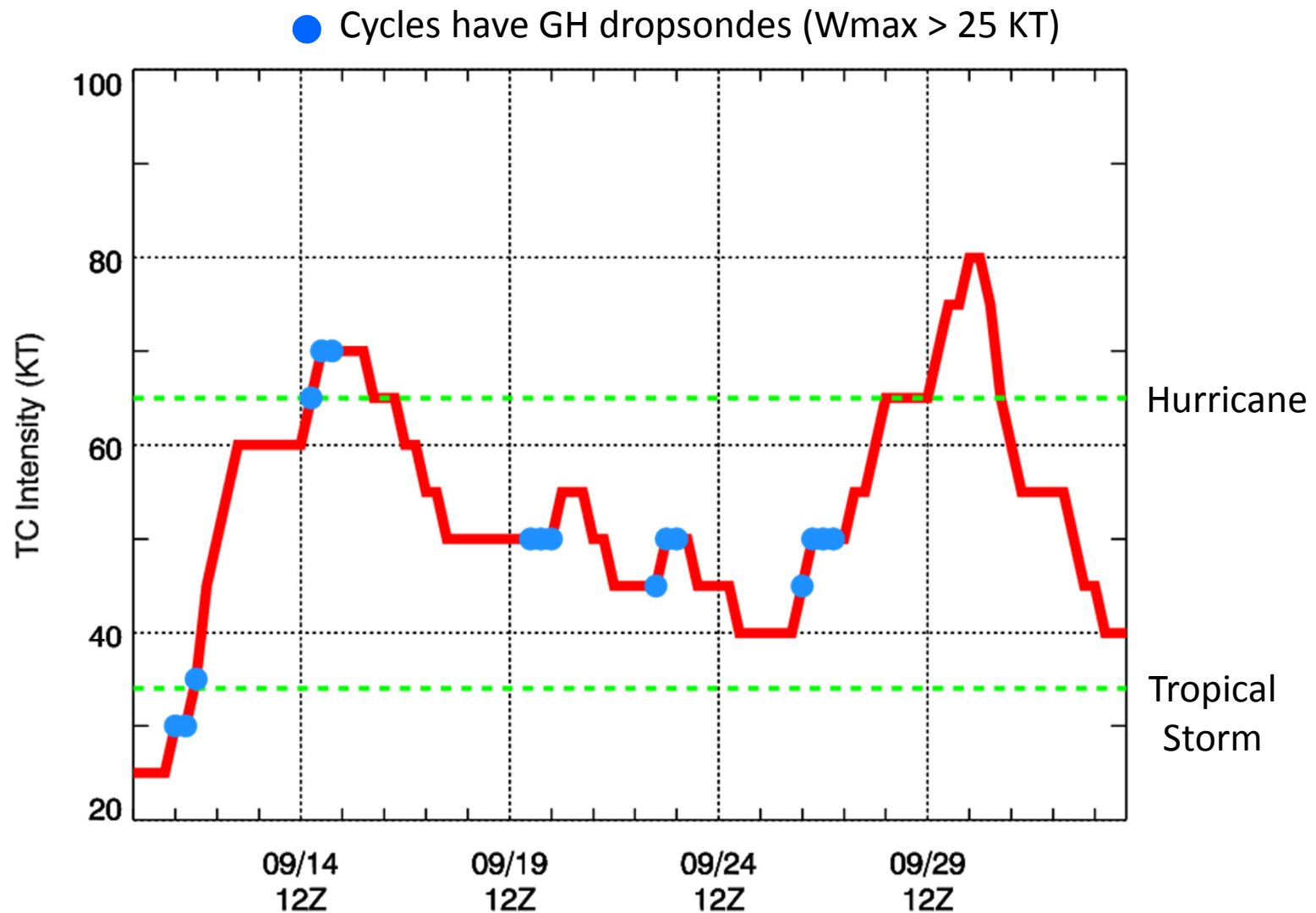
# Assimilation of GH dropsondes in HWRF

EXP	Description
<b>HWRF</b>	<ul style="list-style-type: none"><li>Operational HWRF 2013</li></ul>
<b>DSA2</b>	<ul style="list-style-type: none"><li>Proposed 2014 configuration of operational HWRF</li><li>Based on operational HWRF 2013 plus<ul style="list-style-type: none"><li>raised model top (from 50 hPa to 2 hPa)</li><li>increased vertical levels ( from 43 to 61)</li></ul></li><li>Assimilate conventional and clear-sky satellite radiance data only in the nested domains</li><li>Assimilate conventional + GH dropsondes in inner domain</li></ul>
<b>DSB2</b>	<ul style="list-style-type: none"><li>Based on DSA2</li><li>Assimilate GH dropsondes with reduced obs error in inner domain</li></ul>



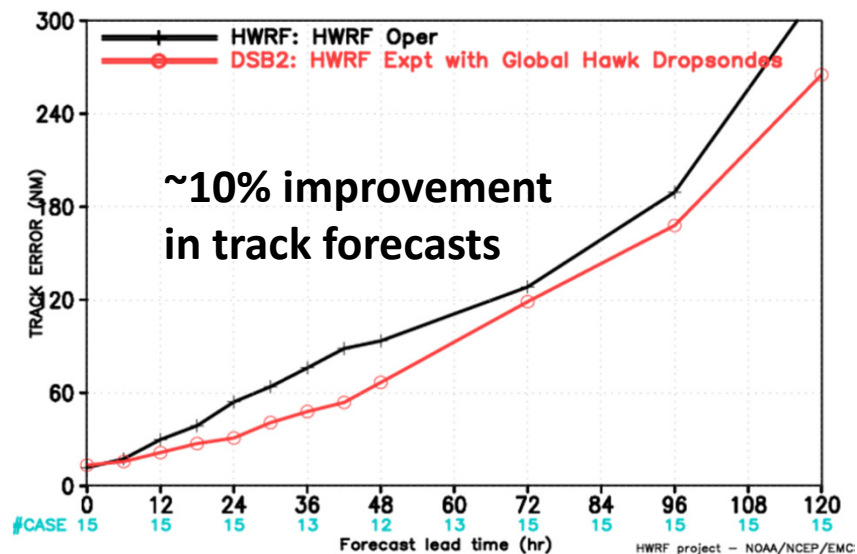
- **Observation errors:**
  - Temperature, moisture, and wind errors are assigned as a function of vertical pressure
- **Potential issues with GH dropsondes assimilation:**
  - When available, data has good temporal and spatial coverage in the inner domain; however data is not available for every cycle
  - Dropsondes drift problem; the GPS measured geo-locations at each pressure level are not included in PREPBUFR

# Life Cycle of **NADINE** 14L 2012

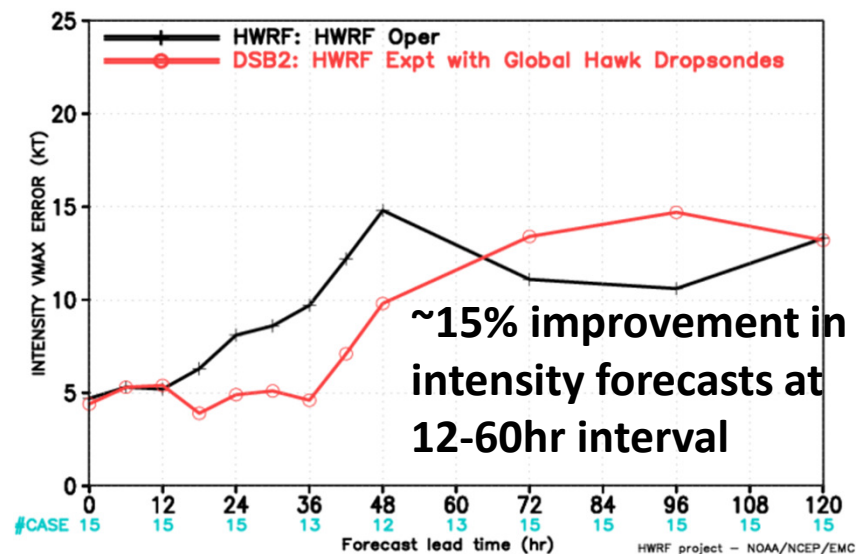


# Hurricane Nadine 14L 2012

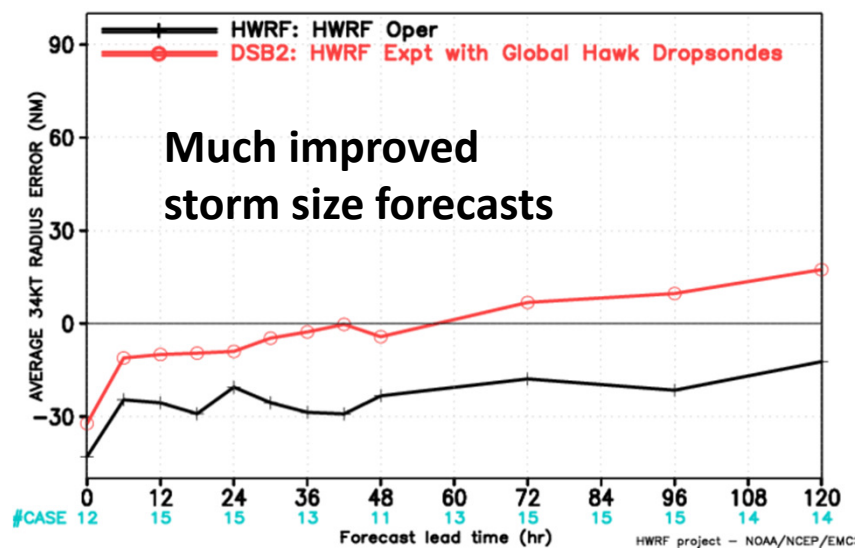
HWRP FORECAST – TRACK ERROR (NM) STATISTICS  
NADINE 14L 2012



HWRP FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS  
NADINE 14L 2012

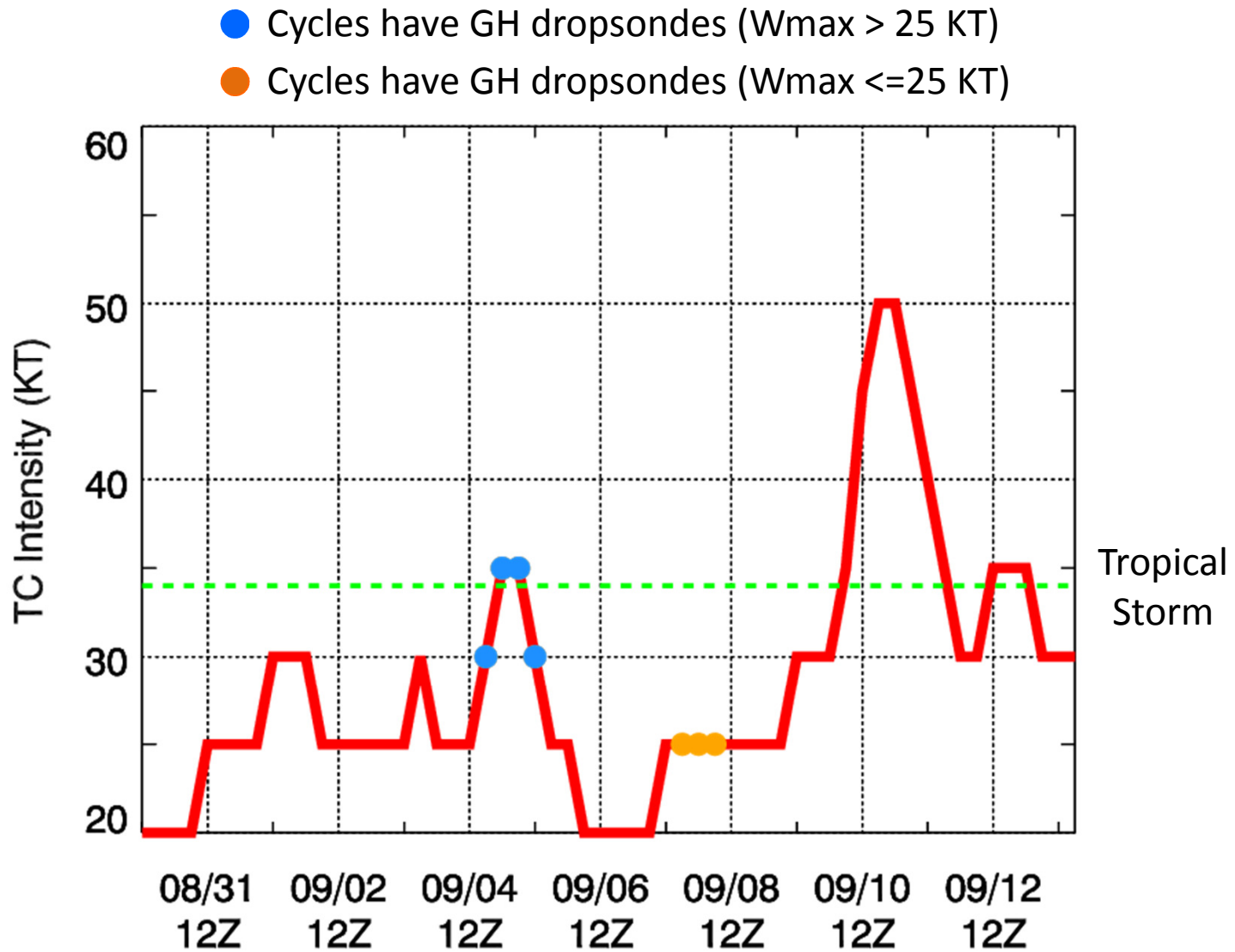


HWRP FORECAST – AVERAGE 34KT RADIUS ERROR (NM) STATISTICS  
NADINE 14L 2012



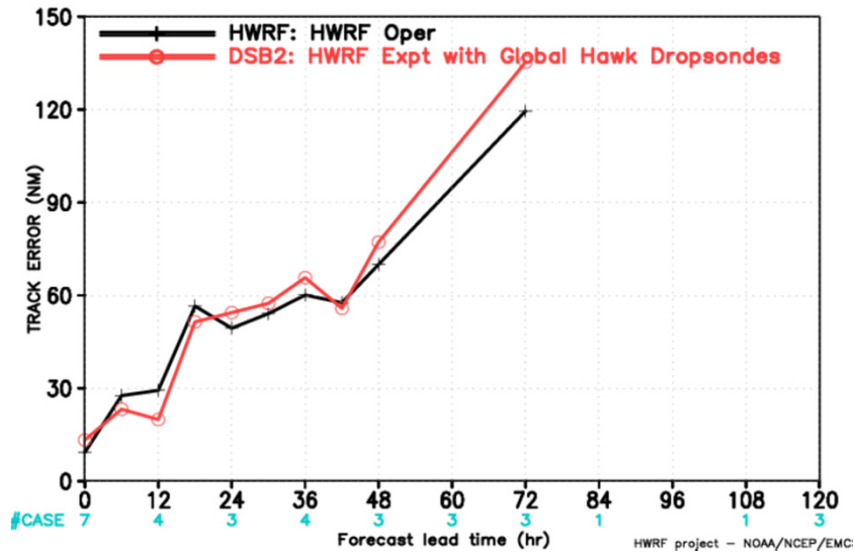
Verification for HWRP track and intensity forecast from cycles with Global Hawk dropsondes

# Life Cycle of **Gabrielle** 07L 2013

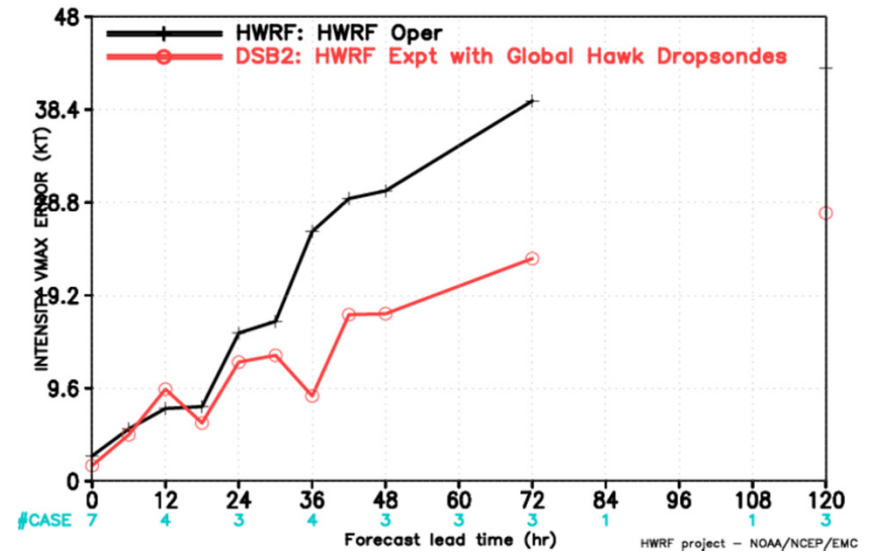


# Gabrielle 07L 2013

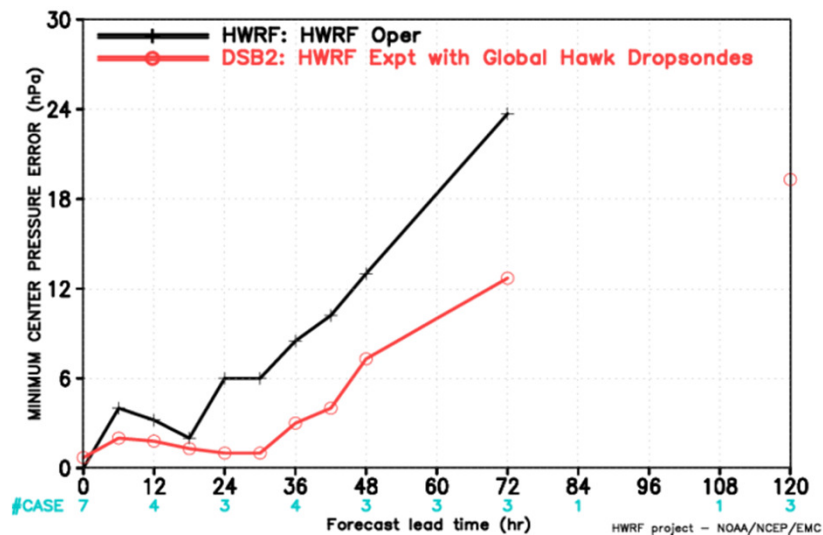
HWRF FORECAST – TRACK ERROR (NM) STATISTICS  
GABRIELLE 07L 2013



HWRF FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS  
GABRIELLE 07L 2013



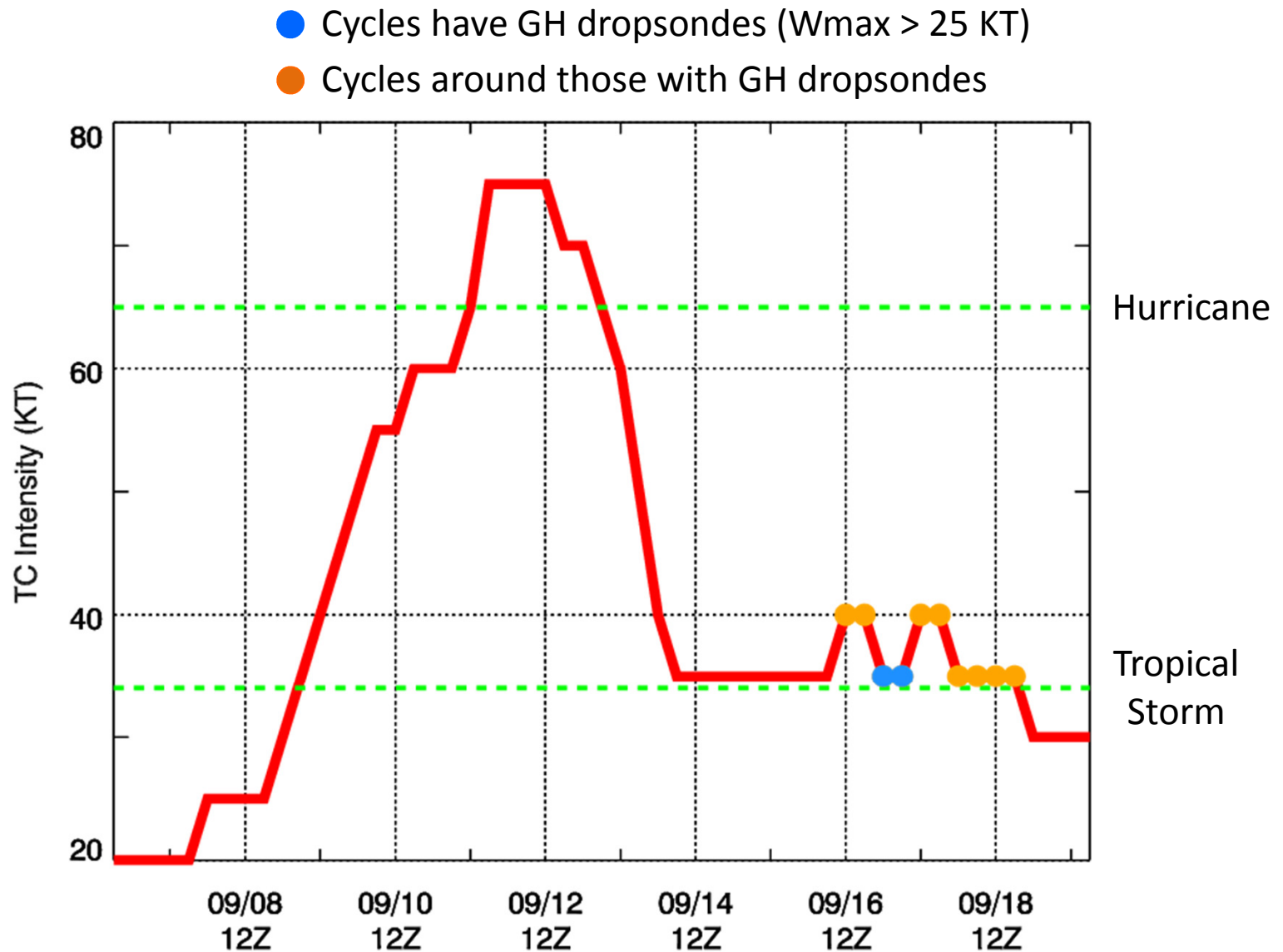
HWRF FORECAST – MINIMUM CENTER PRESSURE ERROR (hPa) STATISTICS  
GABRIELLE 07L 2013



Verification for HWRF forecasts for TS Gabrielle: much improved intensity forecasts

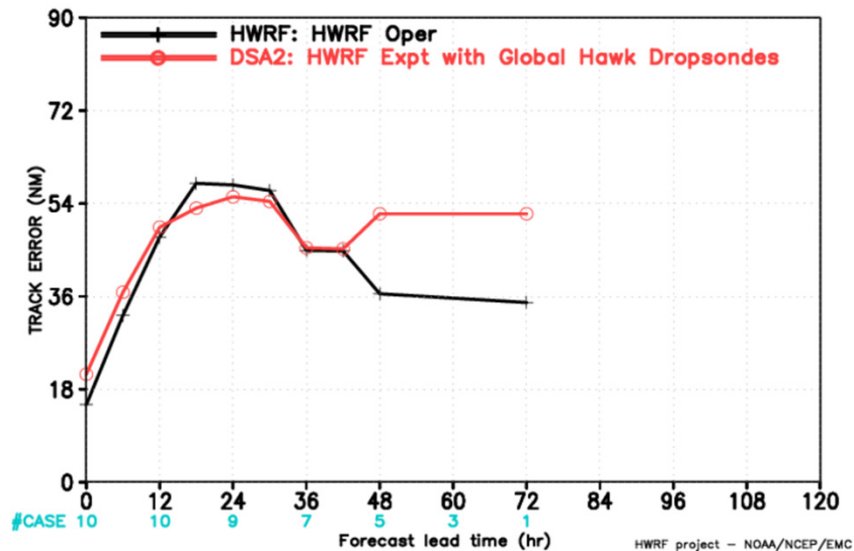


# Life Cycle of **Humberto** 2013

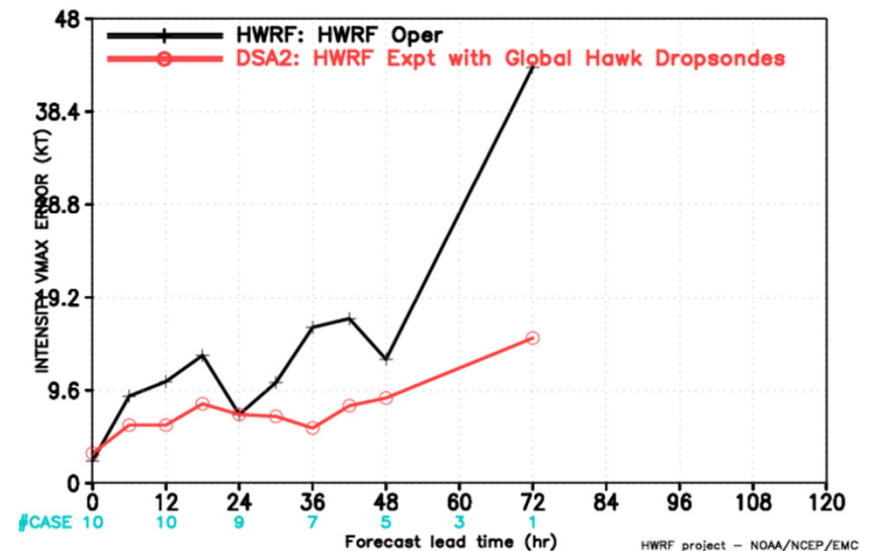


# Humberto 09L 2013

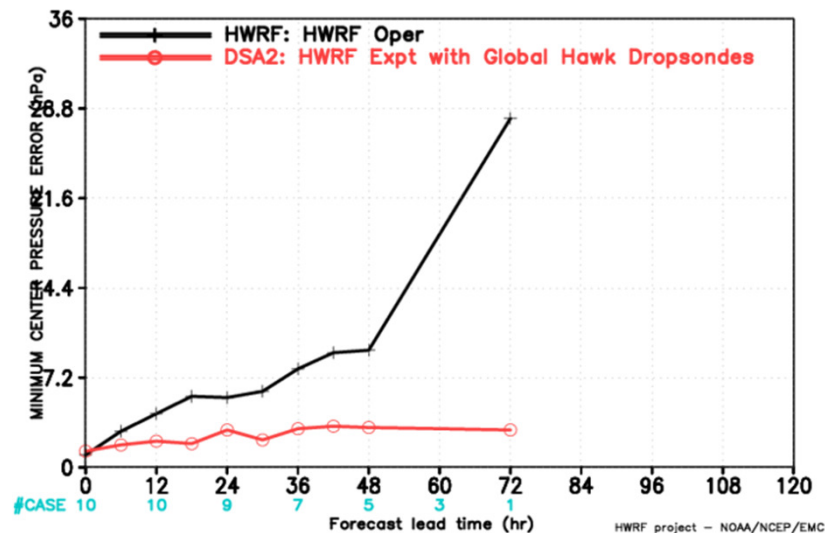
HWRf FORECAST – TRACK ERROR (NM) STATISTICS  
HUMBERTO 09L 2013



HWRf FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS  
HUMBERTO 09L 2013



HWRf FORECAST – MINIMUM CENTER PRESSURE ERROR (hPa) STATISTICS  
HUMBERTO 09L 2013

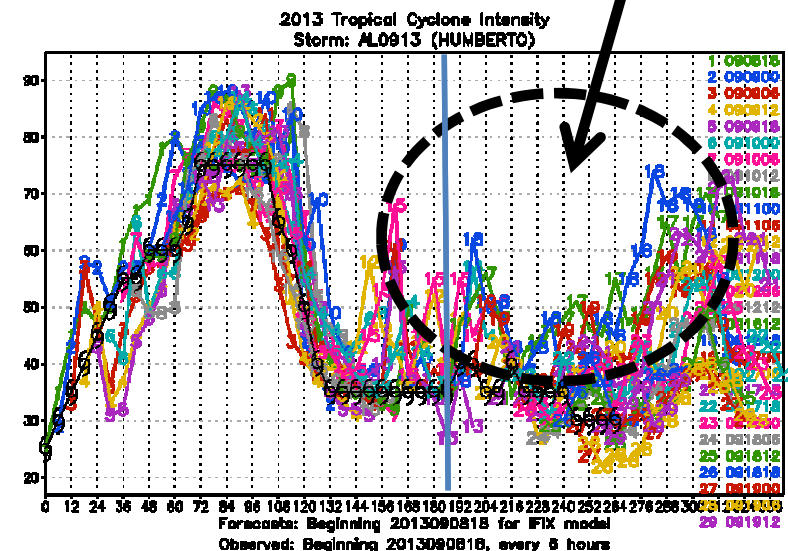
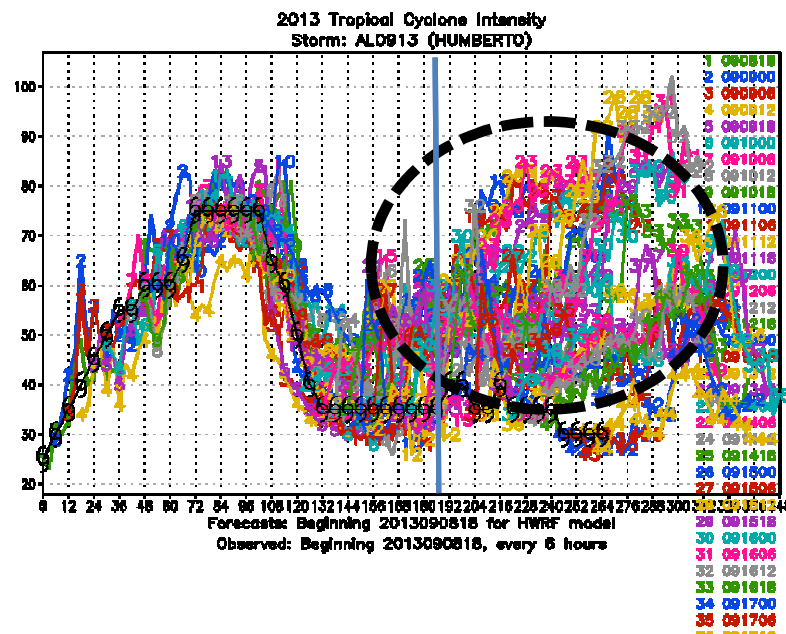


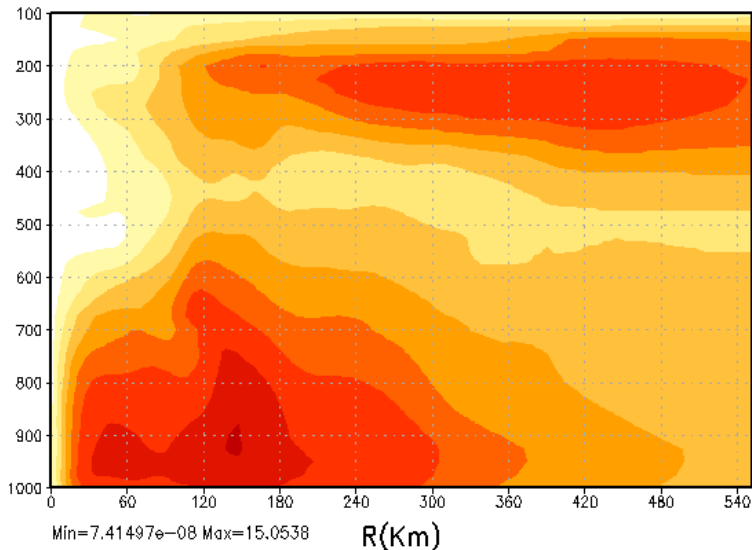
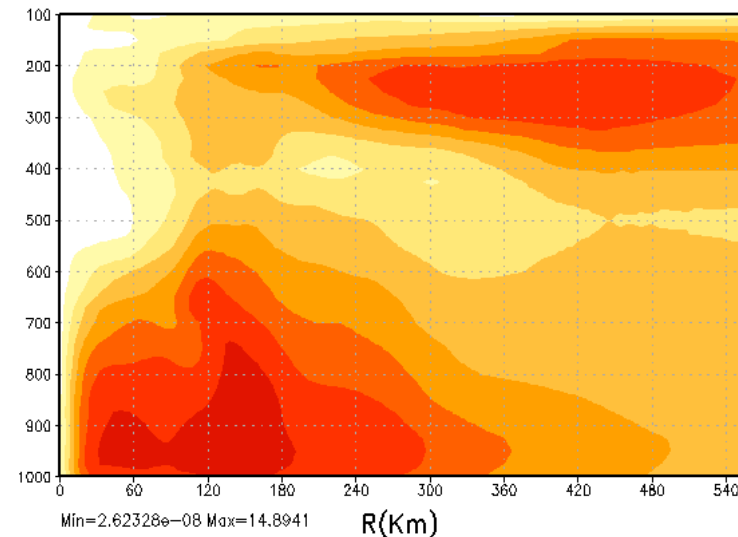
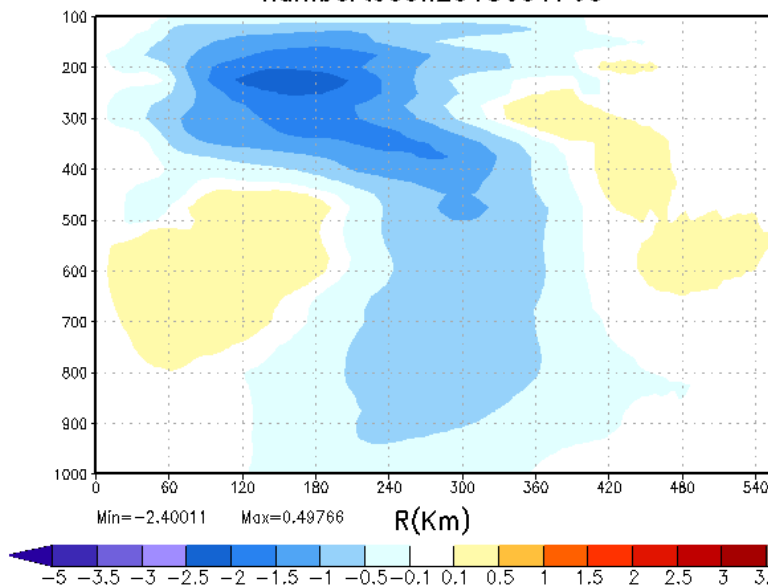
Verification for HWRf forecasts for H. Humberto: Much improved intensity forecasts

# Impact of changes to Data Assimilation and Vortex Initialization for 2014 HWRF

1. Match the initial maximum wind speed over the lands
2. Remove the vorticity discontinuity along the filter domain
3. Avoid cold starts for the first cycle of named/numbered storm through cycling of vortex from Invest cases
4. Assimilate all available aircraft data (TDR and dropsondes including those from P3/GIV, no SFMR/FL)
5. Adding HS3 dropsondes gave expected benefits

**Strong intensity bias reduced**



**H214**H214 WindSpeed(m/s) at F000  
humberto09I.2013091700**HS3**HHS3 WindSpeed(m/s) at F000  
humberto09I.2013091700**diff**HHS3-H214 WindSpeed(m/s) at F000  
humberto09I.2013091700

# Humberto2013091700

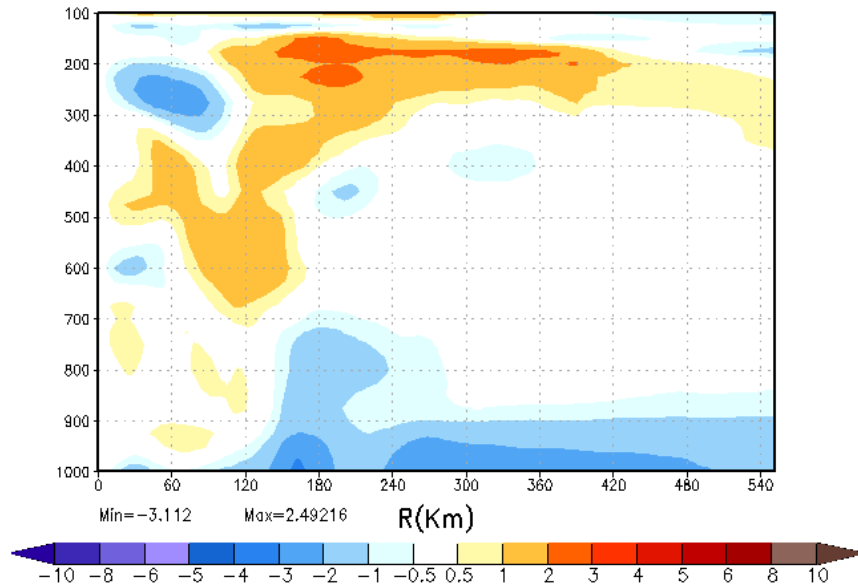
(31 drops) First cycle with many dropsondes

Weak case

Azimuthally-mean Wind speed

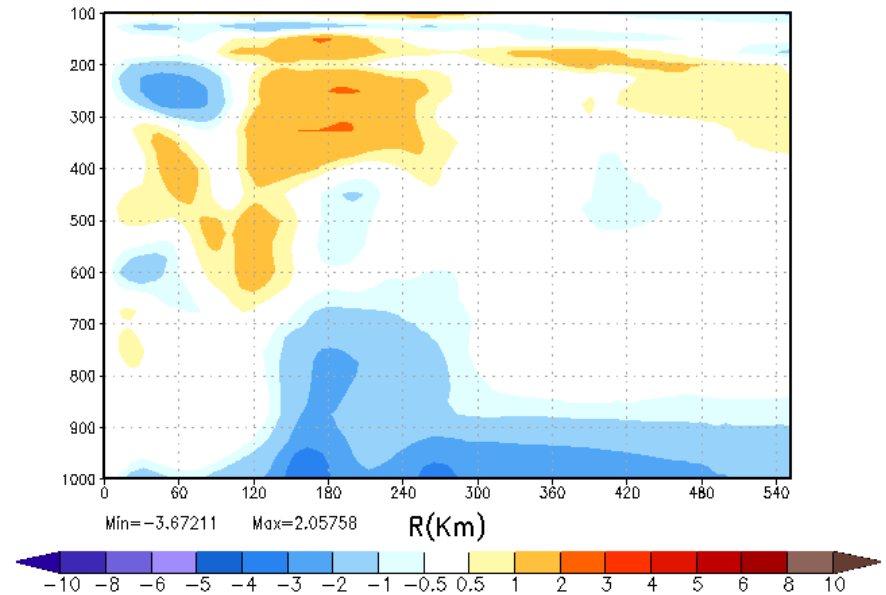
# H214

H214 RadialWind(m/s) at F000  
humberto09I.2013091700



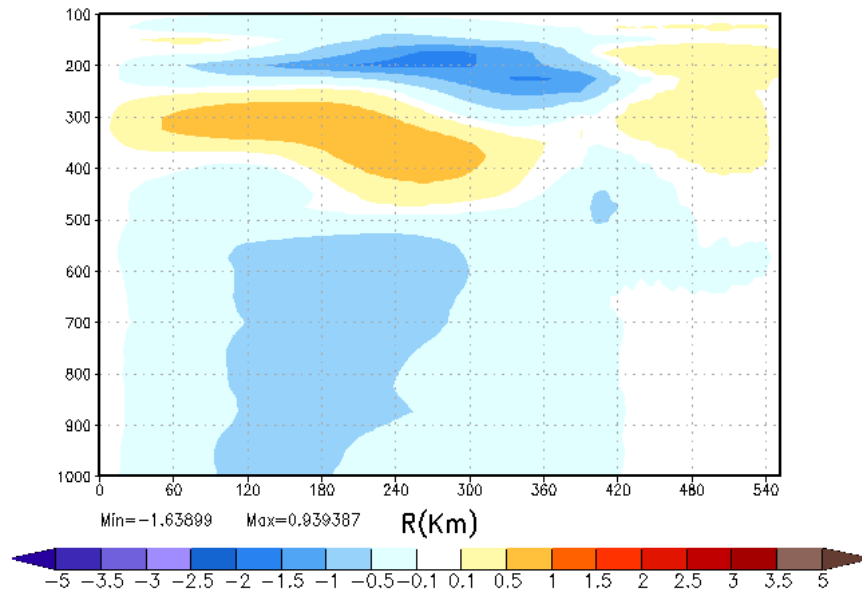
# HS3

HHS3 RadialWind(m/s) at F000  
humberto09I.2013091700



# diff

HHS3-H214 RadialWind(m/s) at F000  
humberto09I.2013091700

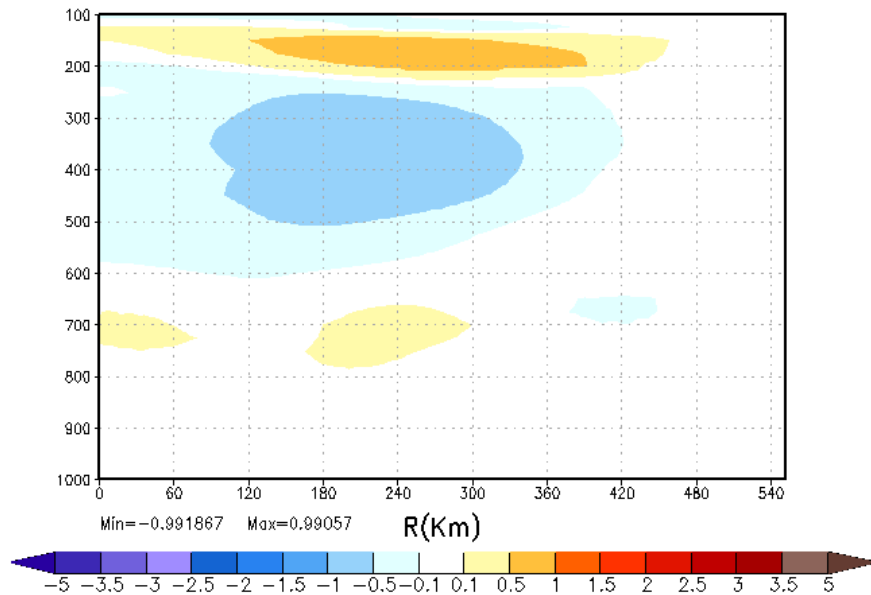


Radial wind  
(inflow, -, outflow +)



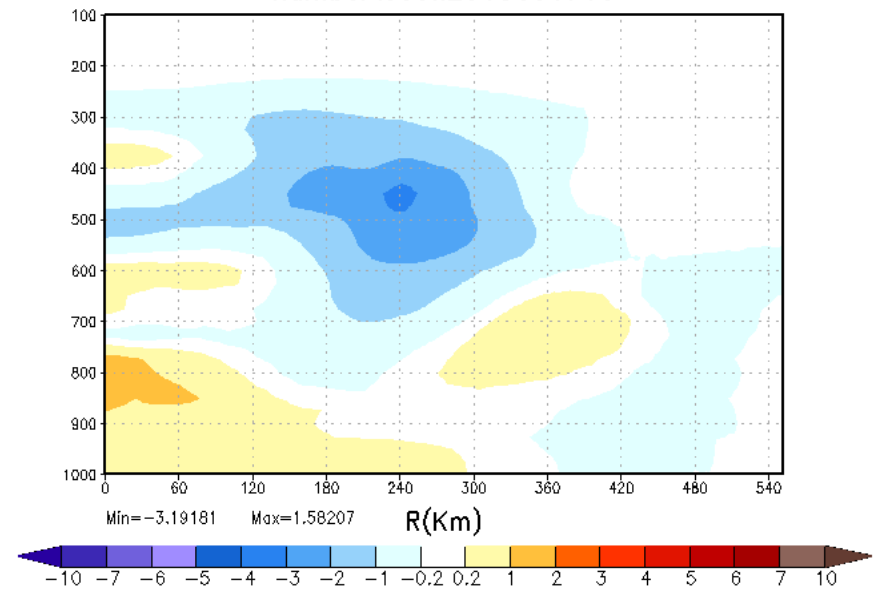
## Difference of Azimuthally-mean Temperature (K)

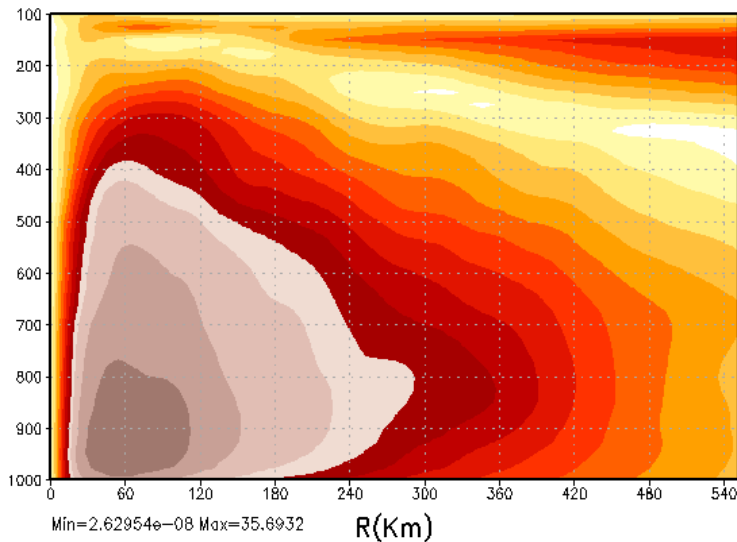
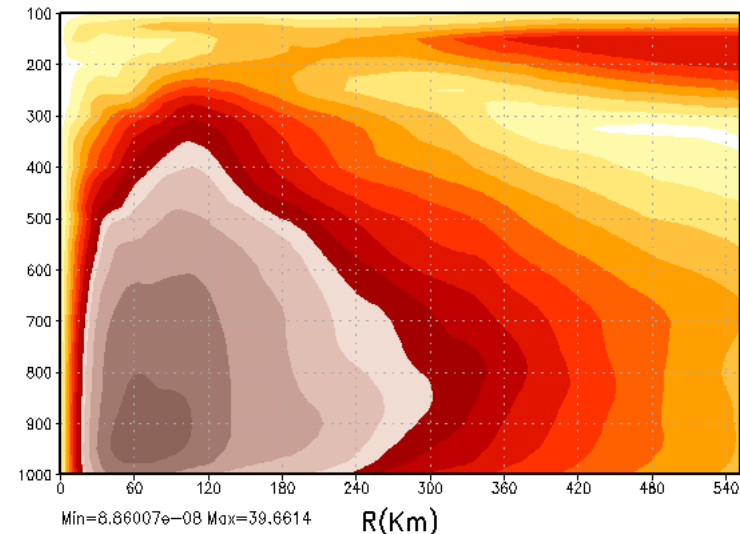
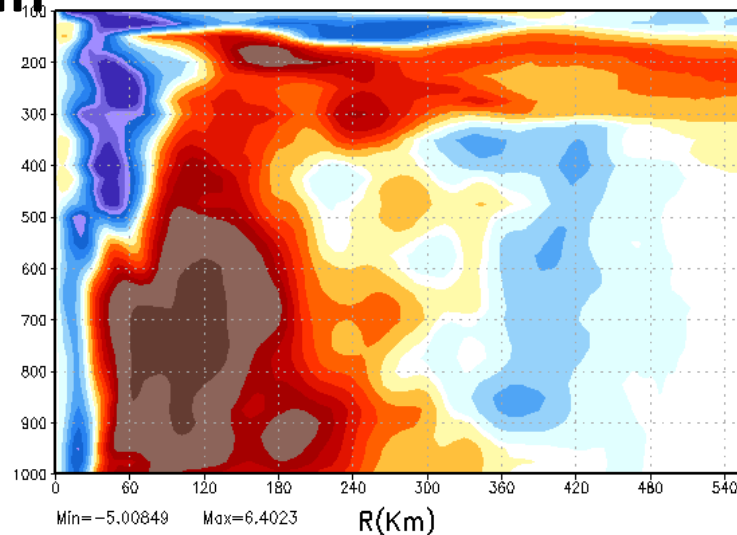
HHS3-H214 Temperature(K) at F000  
humberto09l.2013091700



## Difference of Azimuthally-mean Qv (0.1g/kg)

HHS3-H214 Qv(x0.1k/kg) at F000  
humberto09l.2013091700

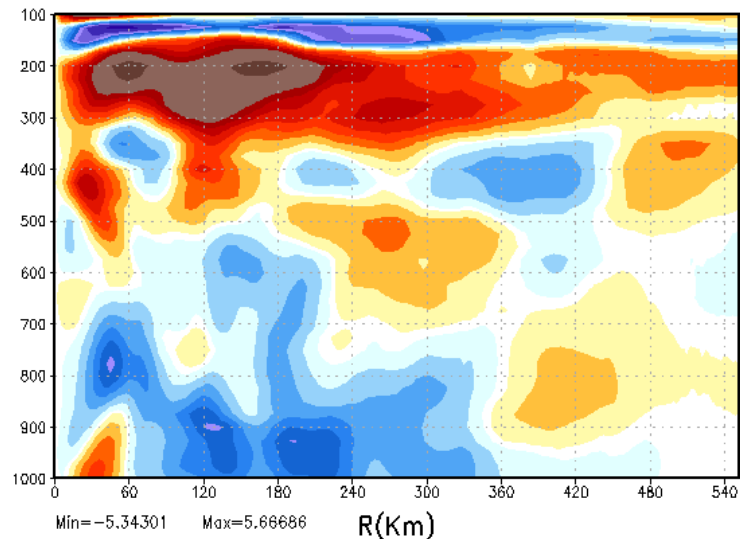
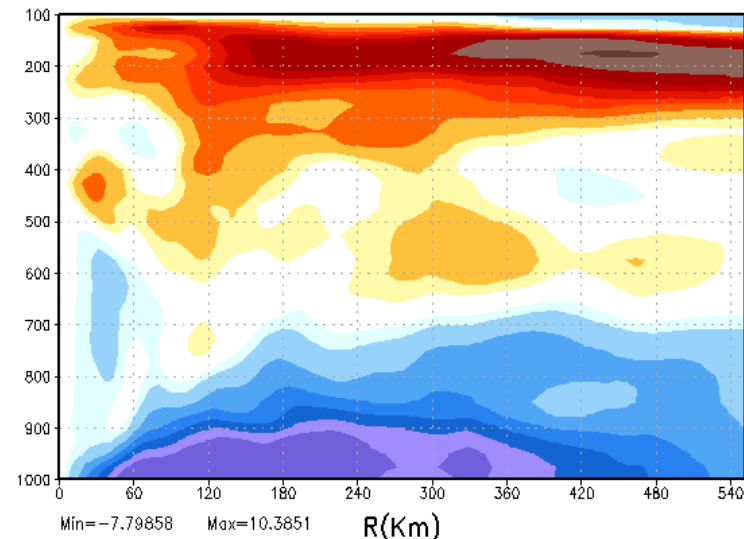
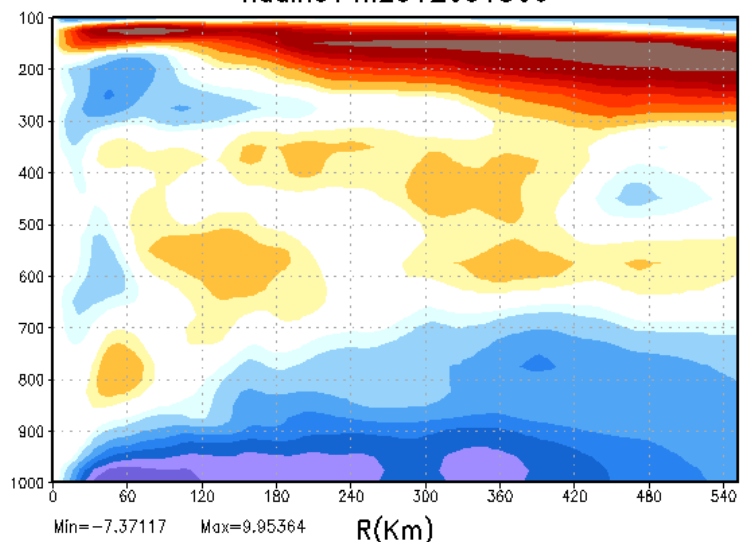


**H214**H214 WindSpeed(m/s) at F000  
nadine14l.2012091506HHS3 WindSpeed(m/s) at F000  
nadine14l.2012091506**HS3****diff**  
HHS3-H214 WindSpeed(m/s) at F000  
nadine14l.2012091506**Nadine 2012091506**

(30 drops)

Strong case

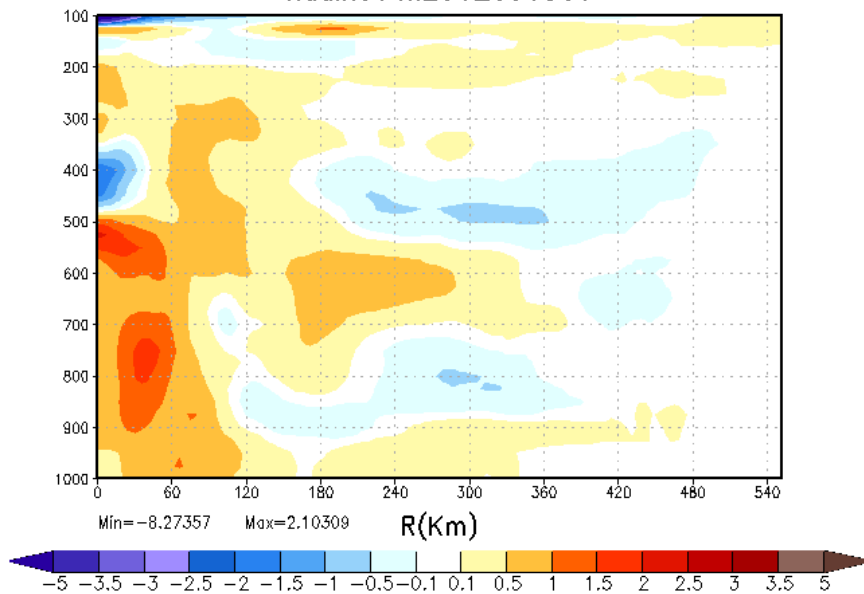
Azimuthally-mean Wind speed

**H214**HHS3-H214 RadialWind(m/s) at F000  
nadine14i.2012091506**HS3**HHS3 RadialWind(m/s) at F000  
nadine14i.2012091506**diff**H214 RadialWind(m/s) at F000  
nadine14i.2012091506

Radial wind  
(inflow, -, outflow +)

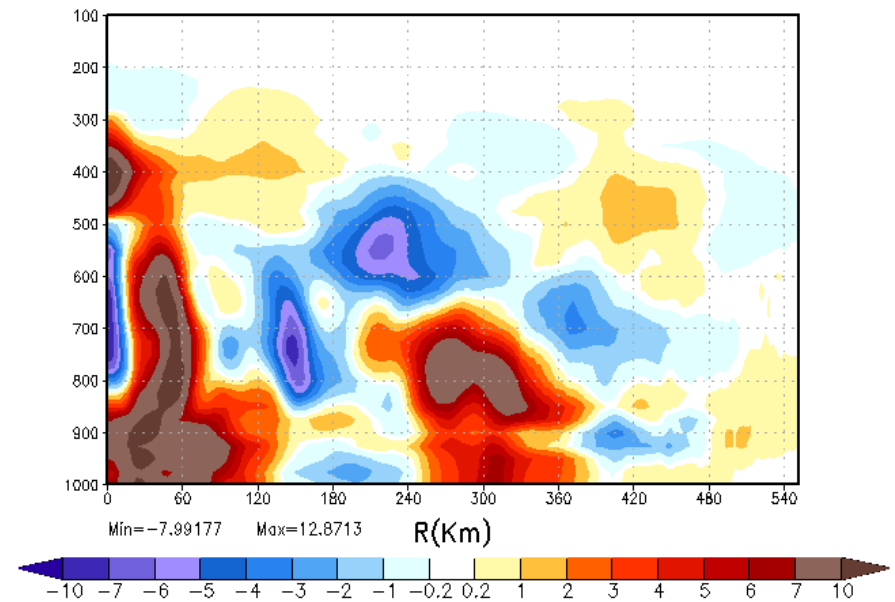
## Difference of Azimuthally-mean Temperature (K)

HHS3-H214 Temperature(K) at F000  
nadine14l.2012091506



## Difference of Azimuthally-mean Qv (0.1g/kg)

HHS3-H214 Qv(x0.1k/kg) at F000  
nadine14l.2012091506



# Summary

- HWRF Data Assimilation System (HDAS) is configured to assimilate HS3 GH Dropsondes in the environment (outer domain) and in the inner core area (3 km nest).
- Several different experiments were designed: Control (2013 operational HWRF); GH dropsonde assimilation experiment with assigning original obs errors (**DSA2**); and another experiment with reduced obs errors by half (**DSB2**)
- All available GH dropsondes were assimilated and experiments were run to assess the impact on hurricane track, intensity and size forecasts.
- Impact from “direct” assimilation cases and “overall” impact was assessed for three storms Hurricane Nadine (2012), TS Gabrielle (2013) and TS Humberto (2013). A few cases with dropsonde data did not qualify as Tropical Storms.
- A general positive impact on track and intensity forecasts was noted from the assimilation of GH dropsondes, and the experiment with reduced obs errors is found to produce better results compared to the initial attempts assigned with original obs errors in the DA system
- Along with assimilation of other aircraft recon data (TDR and dropsondes from NOAA aircraft), HWRF model is capable of assimilating HS3 GH dropsondes in real-time for 2014 season when available.
- Future studies will explore further optimum utilization of GH sondes along with HIRAD/HIWRAP.
- Impact studies will focus on identifying the contribution from
  - Inner core vs. environmental dropsondes
  - Information from lower troposphere (below 400 hPa) vs. from above 400 hPa